

# The effect of the GoodSAM volunteer first-responder app on survival to hospital discharge following out-of-hospital cardiac arrest

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## Aims

Bystander cardiopulmonary resuscitation and defibrillation can double survival to hospital discharge in out-of-hospital cardiac arrest. Mobile phone applications, such as GoodSAM, alerting nearby volunteer first-responders about out-of-hospital cardiac arrest could potentially improve bystander cardiopulmonary resuscitation and defibrillation, leading to better patient outcomes. The aim of this study was to determine GoodSAM's effect on survival to hospital discharge following out-of-hospital cardiac arrest.

## Methods and results

We collected data from the Out-of-Hospital Cardiac Arrest Outcomes Registry (University of Warwick, UK) submitted by the London Ambulance Service (1 April 2016 to 31 March 2017) and East Midlands Ambulance Service (1 January 2018 to 17 June 2018) and matched out-of-hospital cardiac arrests to GoodSAM alerts. We constructed logistic regression models to determine if there was an association between a GoodSAM first-responder accepting an alert and survival to hospital discharge, adjusting for location type, presenting rhythm, age, gender, ambulance service response time, cardiac arrest witnessed status, and bystander actions. Survival to hospital discharge was 9.6% (393/4196) in London and 7.2% (72/1001) in East Midlands. A GoodSAM first-responder accepted an alert for out-of-hospital cardiac arrest in 1.3% (53/4196) cases in London and 5.4% (51/1001) cases in East Midlands. When a responder accepted an alert, the adjusted odds ratio for survival to hospital discharge was 3.15 (95% CI: 1.19–8.36,  $P=0.021$ ) in London and 3.19 (95% CI: 1.17–8.73,  $P=0.024$ ) in East Midlands.

## Conclusion

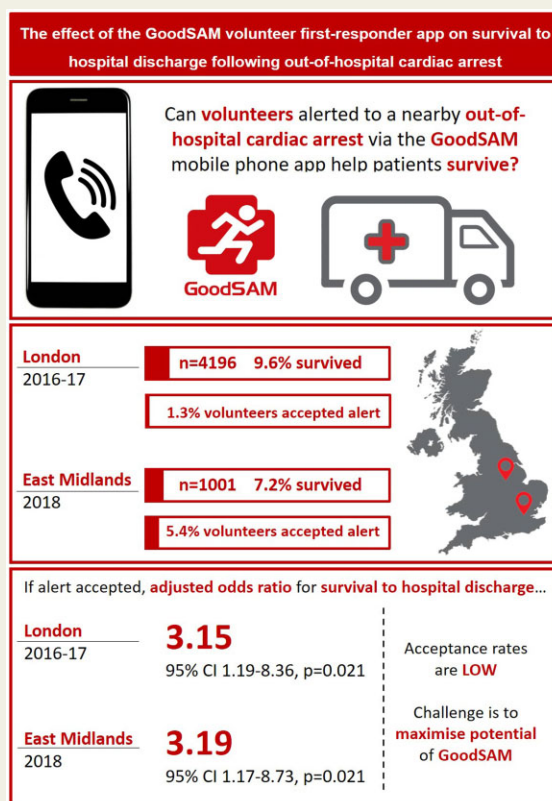
Alert acceptance was associated with improved survival in both ambulance services. Alert acceptance rates were low, and challenges remain to maximize the potential benefit of GoodSAM.

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## Graphical Abstract



**Keywords** Out-of-hospital cardiac arrest • CPR • Bystander defibrillation • Volunteer first-responders

## Introduction

Around 1 in 10 people survive to hospital discharge or 1 month after an out-of-hospital cardiac arrest (OHCA).<sup>1-4</sup> Bystander cardiopulmonary resuscitation (CPR) and defibrillation using an automated external defibrillator (AED) can at least double survival.<sup>5,6</sup>

Providing early access to trained bystanders capable and willing to provide these interventions could impact upon survival. There are a number of mobile-phone applications ('apps') worldwide that aim to activate volunteer first-responders near to an OHCA, who may then be able to provide assistance such as CPR and/or AED use.<sup>7</sup>

GoodSAM is one such system. It operates internationally and is now fully integrated into ambulance services in the UK, Australia, and New Zealand. During an emergency call, if an Emergency Medical Service (EMS) call-handler suspects OHCA and allocates a relevant code from the Computer-Assisted Dispatch (CAD) system, the system automatically activates GoodSAM. GoodSAM automatically sends an alert via the app to trained responders within a specified radius of the OHCA incident, asking if they are able to respond. The GoodSAM response is supplementary to the statutory EMS response.<sup>8</sup>

The aim of this study was to determine the effect of GoodSAM on OHCA survival to hospital discharge in two UK ambulance services.

## Methods

### System description

London Ambulance Service (LAS) covers an area of ~620 square miles and serves ~8.9 million people. It responds to over 1.1 million emergency incidents each year.<sup>9</sup> East Midlands Ambulance Service (EMAS) covers an area of ~6425 square miles and serves ~4.8 million people. It responds to over 730 000 emergency incidents each year.<sup>10</sup>

GoodSAM is a mobile phone app that users can download on multiple platforms (Android, iOS, Windows). Registration and subsequent use of the app requires at least a valid CPR qualification, or evidence of a professional healthcare qualification (e.g. doctor, nurse, paramedic, Emergency Medical Technician). GoodSAM verifies this information, by upload of certificate or professional registration number. Partner organizations such as ambulance and other emergency services can also verify users who work for their own organization. GoodSAM has a Code of Conduct for its users, a detailed Data Protection Policy, and is registered with the Information Commissioner's Office (ref: ZA094052). Data are encrypted

using a 256-bit Advanced Encryption Standard (AES-256) cipher. There is some limited data sharing at the time that a responder accepts an alert (e.g. local ambulance services will have access to information about responders' locations at that time), but no data are shared with other third parties.<sup>8</sup>

Both LAS and EMAS use a version of the Medical Priority Dispatch System. During a 999 call, GoodSAM is automatically activated if a call-handler allocates a dispatch code on the CAD system that indicates a possible OHCA—each ambulance service determines this in advance (see [Table 1](#)). These codes include both adult and paediatric cases but exclude traumatic cases where cardiac arrest is confirmed or suspected. If the call-handler subsequently changes the dispatch code during the 999 call to a code not shown in [Table 1](#), the GoodSAM responder automatically receives an updated notification that the alert has been cancelled.

GoodSAM tracks real-time position of a responder's phone and can send an alert (as an audible siren) to responder(s) within a specified radius of the potential OHCA. In London, at the time of the study, GoodSAM alerted up to three responders within a 300 m radius of an incident and in East Midlands, GoodSAM alerted up to five responders within 800 m. This process is fully automated and not visible to the 999 call-handler. If the allocated code changes (to one not indicating cardiac arrest), GoodSAM issues a 'stand-down' or cancel notification to the phone.

Responders accept or reject an alert via a button press in-app. If one or more responders rejects or does not respond to the alert within 15 s, GoodSAM sends a further alert to the next nearest responder (up to the maximum number) if they are within the specified range. The alert will remain active on the phone for up to 15 min.

Once a GoodSAM responder accepts an alert, the app provides a route to the patient. The screen also displays a brief descriptor, based on the criteria in [Table 1](#) (e.g. 'cardiac arrest—not breathing at all'). If there is a nearby AED, this is displayed via the app too. There is additional functionality in the app for a responder to indicate when they have reached the scene, and if they are carrying an AED. As these are optional, we could not use this to reliably indicate who arrived on scene (with or without an AED).

[Figure 1](#) is a flow chart illustrating the GoodSAM activation process and [Figure 2](#) shows the appearance of (the sequentially appearing) mobile phone screens seen during an alert.

In the UK, there is no legal obligation for a GoodSAM responder to accept an alert, and by not attending the statutory ambulance service response is not affected in any way. In England and Wales, the Social Action, Responsibility and Heroism Act (2015) may provide additional protections, but there is no case law. There has been no successful litigation against anyone who intervened to provide life-saving treatment to a person who had sustained an OHCA.<sup>11</sup>

By 2020, GoodSAM had more than 40 000 registered responders for OHCA, and had the locations (and, where known, the hours when it could be accessed) for more than 50 000 AEDs.

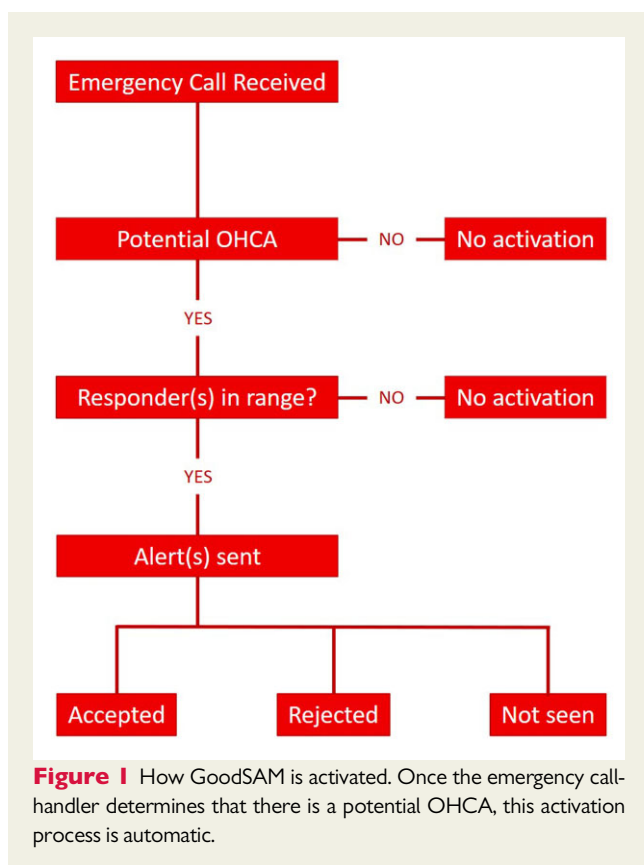
## Data collection

LAS and EMAS both submit data on all-cause OHCA, when they either initiated or continued resuscitation, to the national Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) registry at the University of Warwick. We collected and have presented data for LAS between 1 April 2016 and 31 March 2017 and for EMAS between 1 January 2018 and 17 June 2018. In London, GoodSAM was non-operational from 30 August 2016 to 19 September 2016 and from 26 December 2016 to 30 December 2016, so results that we present exclude OHCA on those dates.

We collected the following data from the OHCAO registry: patient age (years); patient gender (male/female); date/time of 999 call connected to EMS; time EMS stopped on scene; OHCA location; OHCA witnessed by (EMS/bystander/unwitnessed); CPR performed by (EMS/bystander/unwitnessed); public-access AED used by public (yes/no—available for LAS only); initial cardiac arrest rhythm [ventricular fibrillation or ventricular tachycardia (VF/VT)/pulseless electrical activity (PEA)/asystole]; return of spontaneous circulation (ROSC) at hospital handover (yes/no); and survival to hospital discharge (yes/no). We calculated the ambulance response time as the difference between the time EMS stopped on scene and the time of 999 call connected to EMS.

**Table 1** Criteria for GoodSAM activation following potential OHCA (at the time of study)

London Ambulance Service	East Midlands Ambulance Service
Cardiac arrest—not breathing at all	Breathing problems—ineffective breathing
Respiratory arrest—breathing uncertain (agonal)	Burns/explosion—unconscious or cardiac arrest
Respiratory arrest/ineffective breathing	Cardiac/respiratory arrest
Complete obstruction/ineffective breathing	Chest pain—not alert/breathing problems
Fitting and not breathing	Choking—complete obstruction
Fitting and not breathing—fitting history	Convulsions—not breathing
Unconscious or fainting—ineffective breathing	Drowning—unconscious or cardiac arrest
Unconscious, agonal/ineffective breathing	Electrocution—not breathing
Unconscious or cardiac arrest	Fall—unconscious or cardiac arrest
	Heart problems—not alert/just resuscitated
	Unconscious or cardiac arrest
	Unconscious fainting—ineffective breathing
	Unconscious fainting—agonal breathing
	Unknown problem—life status questionable
	Call from 111—possible cardiac arrest
	Call from 111—unconscious and ineffective breathing
	Call from 111—8 min response required



GoodSAM provided the following information: number of 999 calls meeting criteria for GoodSAM alert; number of GoodSAM alerts sent; date/time of GoodSAM alert; number of GoodSAM alerts accepted, not seen, or rejected; and incident location.

We manually matched cases submitted to the OHCAO registry with GoodSAM alerts using date/time of the 999 call and OHCA location. LAS provided incident location as an address and postcode, and we reviewed these to determine whether these were residential or non-residential. EMAS provided location type as per Utstein definition<sup>12</sup> (e.g. residential, public building, street, workplace), supplemented by postcode only, and we dichotomized these as residential or non-residential.

Both ambulance services provided a list of public-access AEDs known to them. OHCA location accuracy was such in London (LAS) that we were able to calculate the distance from each OHCA to its nearest public-access AED.

## Data analysis and reporting

We presented and collected data according to the Utstein guidelines.<sup>12</sup> The primary outcome was survival to hospital discharge. We have presented data for the following groups: GoodSAM alert accepted; GoodSAM alert not seen or rejected; and No GoodSAM alert sent.

Given the different system configurations, we constructed a separate multiple logistic regression model for LAS and EMAS data to determine if there was an association between GoodSAM alert acceptance group (accepted/not seen or rejected/no alert sent) and survival to hospital discharge. In addition to GoodSAM alert acceptance group, the models contained the following independent variables: patient age (years), patient gender (male/female), OHCA witnessed by (EMS/bystander/unwitnessed), CPR performed by (EMS/bystander, not performed), bystander

AED use (yes/no, LAS only), location type (residential/non-residential), initial cardiac arrest rhythm (VF or VT/PEA/asystole); EMS response time (min: s); and distance to nearest AED (m, LAS only). We entered all variables into the model for their potential to impact the outcome in OHCA, with no statistical procedure to determine entry into the model. We considered that all covariates were clinically important variables for which we should adjust. We have presented unadjusted odds ratios (OR) and adjusted ORs with 95% confidence intervals (95% CI).

We used SPSS Statistics (version 24; IBM, New York, USA) for statistical analyses. We analysed differences in patient and process variables between the GoodSAM alert accepted, GoodSAM alert not seen/rejected, and No GoodSAM alert groups using  $\chi^2$  tests for categorical variables and Kruskal–Wallis test for continuous variables.

For the logistic regression modelling, we used Shapiro–Wilk's test to assess for normality of distribution for continuous variables and performed multicollinearity tests, determining that there was no substantial association between variables in the model. We also calculated pseudo- $R^2$  values (Cox and Snell, and Nagelkerke) to indicate how much the predictor variables in the logistic regression model explain the outcome of interest, and the Hosmer–Lemeshow Goodness of Fit test to test the fit of the model and indicate how reliable the estimates provided for the outcome measure were.<sup>13</sup>

## Research governance and ethical approvals

The OHCAO registry has approval from the Health Research Authority (reference number 13/SC/036) and Confidentiality Advisory Group (reference number ECC8-04(C)/2013). The registry granted approval for the use of non-identifiable data for the analyses described above.

The Biomedical and Scientific Research Ethics Committee at the University of Warwick (REGO 2018-2157) approved the study-specific protocols for collection and analysis of data on 6 March 2018 (LAS data) and 29 October 2018 (EMAS data). We held all data on a secure University server in encrypted folders.

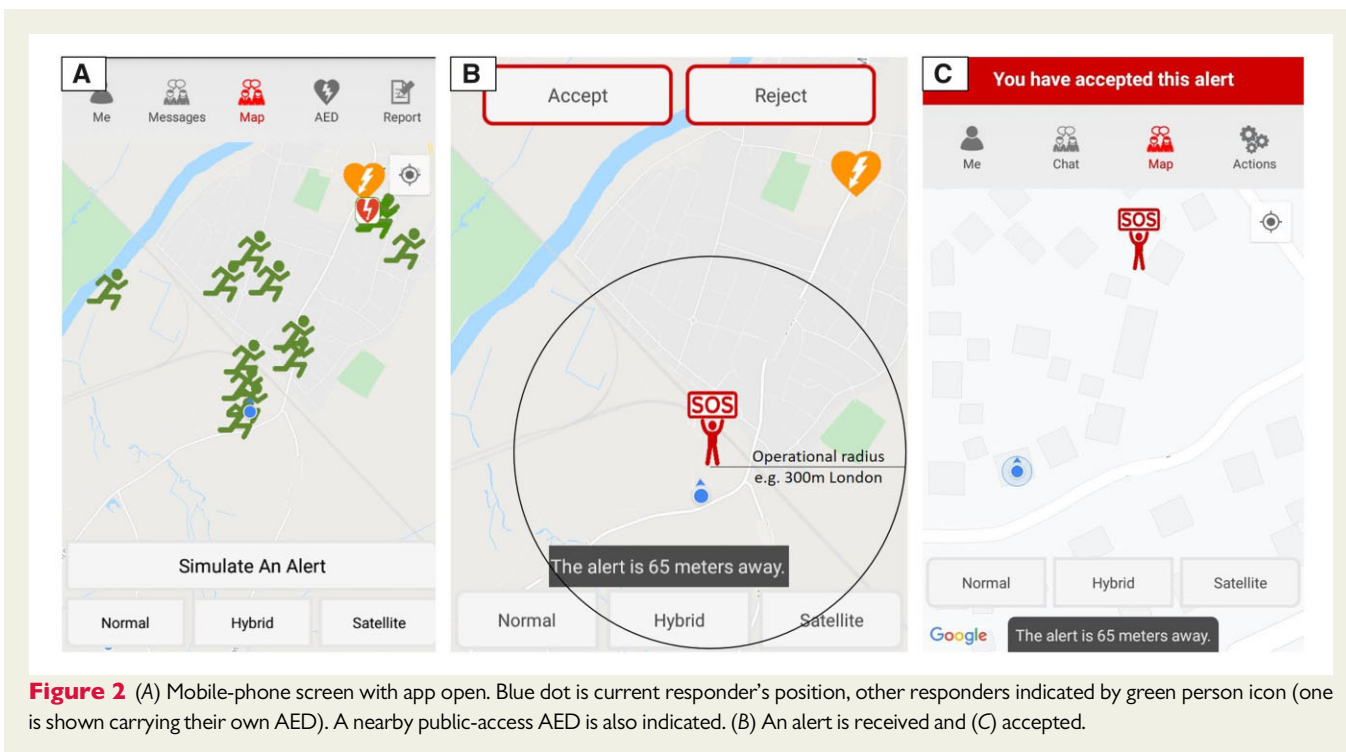
## Results

### London

There were 11 894 emergency calls that fulfilled the criteria for a GoodSAM alert, and 4196/11 894 (35%) were confirmed OHCA. Amongst these 4196 confirmed OHCA, GoodSAM issued 354 alerts for the 282 (6.7%) cases when at least one responder was within a 300 m radius. A GoodSAM responder accepted an alert on 56/354 (16%) occasions for 53 OHCA (1.3% of total OHCA). More than one person received an alert on 56 occasions, and on three occasions two people accepted an alert.

### Baseline characteristics for OHCA patients

The median age ( $n = 4164$ , 32 unknown) was 69.3 (IQR: 52.8–80.8) years and 2695/4196 (64%) were male. EMS witnessed 739/4196 (18%) OHCA, bystanders 1985/4196 (47%), and 1472/4196 (35%) were unwitnessed. Bystanders performed CPR in 2211/4196 (53%) OHCA, or 2209/3457 (64%) of the non-EMS-witnessed cases. They attached a public-access AED in 179/4196 (4.3%) OHCA, or 176/3457 (5.1%) of the non-EMS-witnessed cases. OHCA occurred in residential locations in 3447/4111 cases (84%, 85 unknown). Median EMS response time was 7:39 (IQR: 5:45–10:24) min. The median distance to an AED ( $n = 4111$ , 85 unknown) was 407 (IQR: 222–642) m. The initial cardiac rhythm ( $n = 4172$ , 24 unknown) was VF/VT in 916/



**Figure 2** (A) Mobile-phone screen with app open. Blue dot is current responder's position, other responders indicated by green person icon (one is shown carrying their own AED). A nearby public-access AED is also indicated. (B) An alert is received and (C) accepted.

4172 (22%), PEA in 1179/4172 (28%), and asystole in 2077/4172 (50%).

ROSC at hospital was 1219/4196 (29%), and 393/4111 (9.6%, 85 unknown) patients survived to hospital discharge. [Table 2](#) summarizes these data by GoodSAM alert status.

### East Midlands

There were 8768 emergency calls that fulfilled the criteria for a GoodSAM alert, and 1041/8768 (12%) were confirmed OHCA. Amongst these 1041 confirmed OHCA, GoodSAM issued 349 alerts for the 227 (22%) cases when at least one responder was within an 800 m radius. A GoodSAM responder accepted an alert on 54/349 (15%) occasions for 51 OHCA (4.9% of total OHCA). More than one person received an alert on 73 occasions, and on three occasions two people accepted an alert.

#### Baseline characteristics for OHCA patients

The median age ( $n = 1009$ , 32 unknown) was 72 (IQR: 59–83) years and 656/1041 (63%) were male. EMS witnessed 21/1041 (2%) OHCA, bystanders 564/1041 (54%), and 456/1041 (44%) were unwitnessed. Bystanders performed CPR in 647/1041 (62%) OHCA, or 647/1020 (63%) of the non-EMS-witnessed cases. OHCA occurred in residential locations in 868/1033 cases (84%, 8 unknown). Median EMS response time was 9:59 (IQR: 6:16–16:02) min. The initial cardiac rhythm ( $n = 970$ , 71 unknown) was VF/VT in 172/970 (18%), PEA in 204/970 (21%), and asystole in 594/970 (61%).

ROSC at hospital was 1219/4196 (25%), and 72/1001 (7.2%, 40 unknown) patients survived to hospital discharge. [Table 3](#) summarizes these data by GoodSAM alert status.

### Logistic regression models

#### London

Continuous variables were non-normally distributed (Shapiro–Wilk test all  $P < 0.001$ ). There was little dependency between covariates in the model (variance inflation factor (VIF) no more than 1.22 for any variable).

The logistic regression model included data from 3971/4196 (95%) OHCA. Cox and Snell  $R^2$  (0.185) and Nagelkerke  $R^2$  (0.395) suggested that 18.5–39.5% of the variation in survival to hospital discharge could be explained by this model. The  $P$ -value for the Hosmer–Lemeshow Goodness of Fit test was non-significant (0.24), suggesting overall goodness of fit.

The adjusted OR for survival to hospital discharge (compared with death) if a GoodSAM alert was accepted (compared with no alert sent) was 3.15 (95% CI: 1.19–8.36;  $P = 0.021$ ). If the GoodSAM alert 'not seen or rejected' was taken as the reference, the adjusted OR for survival to hospital discharge (compared with death) in the GoodSAM alert accepted group was 3.06 (95% CI: 1.03–9.03;  $P = 0.04$ ). We have presented unadjusted ORs and adjusted ORs for all variables in the model in [Table 4](#) and [Figure 3A](#).

#### East Midlands

Continuous variables were non-normally distributed (Shapiro–Wilk test all  $P < 0.001$ ). There was little dependency between covariates in the model (VIF no more than 1.07 for any variable).

The logistic regression model included data from 907/1041 (87%) OHCA. Cox and Snell  $R^2$  and Nagelkerke  $R^2$  values were 0.109 and

**Table 2** Patient, process, and outcome data by GoodSAM response group (London)

	GoodSAM alert		No GoodSAM alert (n = 3914)
	Accepted (n = 53)	'Not seen' or rejected (n = 229)	
Age (median (IQR), years)*	66.0 (50.0–77.1)	69.4 (54.0–80.0)	69.3 (52.7–80.9)
Unknown cases			32
Gender			
Male	64.2% (34/53)	67.2% (154/229)	64.1% (2507/3914)
Female	35.8% (19/53)	32.8% (75/229)	35.9% (1407/3914)
OHCA witnessed by*			
EMS	3.8% (2/53)	2.2% (5/229)	18.6% (729/3914)
Bystander	58.4% (31/53)	60.7% (139/229)	46.4% (1815/3914)
Unwitnessed	37.8% (20/53)	37.1% (85/229)	35.0% (1367/3914)
Bystander CPR			
All cases*	67.9% (36/53)	64.2% (147/229)	51.8% (2028/3914)
Non-EMS-witnessed	70.6% (36/51)	65.6% (147/224)	63.7% (2026/3182)
Bystander AED			
All cases*	9.4% (5/53)	8.3% (19/229)	4.0% (155/3913)
Non-EMS-witnessed*	9.8% (5/51)	8.5% (19/224)	4.8% (152/3182)
Unknown cases			1
Location type*			
Residential	69.8% (37/53)	72.0% (162/225)	84.7% (3248/3833)
Non-residential	30.2% (16/53)	28.0% (63/225)	15.3% (585/3833)
Unknown cases		4	81
Initial rhythm*			
VF/VT	20.8% (11/53)	29.3% (67/229)	21.5% (838/3890)
PEA	17.0% (9/53)	21.0% (48/229)	28.8% (1122/3890)
Asystole	62.3% (33/53)	49.8% (114/229)	49.6% (1930/3890)
Unknown cases			24
EMS response time*	06:21	06:41	07:45
[median (IQR), min:s]	(04:40–08:15)	(05:08–08:46)	(05:48–10:30)
Distance from nearest AED*	255	312	413
[median (IQR), m]	(134–433)	(140–539)	(228–651)
Unknown cases		5	82
ROSC at hospital	39.6% (21/53)	28.4% (65/229)	28.9% (1133/3914)
Survival to hospital discharge	17.6% (9/51)	10.3% (23/223)	9.4% (361/3837)
Unknown cases	2	6	77

\* $P < 0.05$ .Differences between groups analysed using  $\chi^2$  for categorical variables and Kruskal–Wallis for continuous variables.

0.286, respectively. Hosmer–Lemeshow Goodness of Fit test suggested overall goodness of fit ( $P = 0.60$ ).

The adjusted OR for survival to hospital discharge (compared with death) if a GoodSAM alert was accepted (compared with no alert sent) was 3.19 (95% CI: 1.17–8.73;  $P = 0.024$ ). If the GoodSAM alert 'not seen or rejected' was taken as the reference, the adjusted OR for survival to hospital discharge (compared with death) in the GoodSAM alert accepted group was 4.84 (95% CI: 1.34–17.5;  $P = 0.016$ ). We have presented unadjusted ORs and adjusted ORs for all variables in the model in [Table 5](#) and [Figure 3B](#).

## Discussion

### Main findings

Accepting a GoodSAM alert was associated with improved survival to hospital discharge in adjusted analyses during the study periods in London (adjusted OR: 3.15; 95% CI: 1.19–8.36;  $P = 0.021$ ) and East Midlands (adjusted OR: 3.19; 95% CI: 1.17–8.73;  $P = 0.024$ ). Thirty-five per cent of 999 calls meeting the criteria for GoodSAM activation in London, and 12% in East Midlands, were for confirmed OHCA. A GoodSAM responder was close enough to receive an alert for 6.7% confirmed OHCA in London and 22% in East Midlands.

**Table 3** Patient, process, and outcome data by GoodSAM response group (East Midlands)

	GoodSAM alert		No GoodSAM alert (n = 814)
	Accepted (n = 51)	'Not seen' or rejected (n = 176)	
Age [median (IQR), years]*	73.0 (67.8–79.3)	70.0 (56.8–81.0)	72.0 (59.0–82.0)
Unknown cases	3	4	25
Gender			
Male	76.5% (39/51)	64.2% (113/176)	61.9% (504/814)
Female	23.5% (12/51)	35.8% (63/176)	38.1% (310/814)
OHCA witnessed by			
EMS	2.0% (1/51)	0.6% (1/176)	2.3% (19/814)
Bystander	49.0% (25/51)	51.1% (90/176)	55.2% (449/814)
Unwitnessed	49.0% (25/51)	48.3% (85/176)	42.5% (346/814)
Bystander CPR			
All cases*	58.9% (30/51)	74.4% (131/176)	59.7% (486/814)
Non-EMS-witnessed*	60.0% (30/50)	74.9% (131/175)	61.1% (486/795)
Location type			
Residential	80.4% (41/51)	86.4% (152/176)	83.7% (675/806)
Non-residential	19.6% (10/51)	13.6% (24/176)	16.3% (131/806)
Unknown cases			8
Initial rhythm			
VF/VT	26.5% (13/49)	17.9% (30/168)	17.1% (129/753)
PEA	14.3% (7/49)	16.1% (27/168)	22.6% (170/753)
Asystole	59.2% (29/49)	66.1% (111/168)	60.3% (454/753)
Unknown cases	2	8	61
EMS response time*	07:59	07:29	10:46
[median (IQR), mins:]	(05:23–12:57)	(05:26–11:36)	(06:46–17:00)
Unknown cases		2	6
ROSC at hospital	25.5% (13/51)	23.3% (41/176)	24.9% (203/814)
Survival to hospital discharge	15.2% (7/46)	5.3% (9/170)	7.1% (56/785)
Unknown cases	5	6	29

\* $P < 0.05$ .Differences between groups analysed using  $\chi^2$  for categorical variables and Kruskal–Wallis for continuous variables.

A GoodSAM responder accepted alerts for 1.3% confirmed OHCA in London and 4.9% in East Midlands.

### Comparison with the literature

A 2019 Cochrane Library systematic review<sup>14</sup> found one RCT<sup>15</sup> evaluating volunteer first-responder systems. This study, of 676 non-traumatic OHCA in patients aged  $\geq 8$  years, found no improvement in 30 day survival when patients received a supplementary response from volunteer first-responders within a 500 m radius, compared with a standard ambulance service response alone (OR: 1.34; 95% CI: 0.79–2.29). However, the study was not powered for this outcome and did not mention public-access AED use.

Two observational studies reported improved survival to hospital discharge when volunteer first-responders were activated<sup>16</sup> or attended an OHCA patient.<sup>17</sup> Both these studies attempted to account for confounders, by propensity score matching<sup>16</sup> or by multiple logistic regression,<sup>17</sup> but neither accounted for the impact of bystander AED use. A further before-and-after study from South Korea reported an adjusted OR of 1.84 (95% CI: 1.29–2.63) for

survival to hospital discharge and 2.31 (95% CI: 1.44–3.70) for survival with favourable neurological outcome for an intervention bundle to increase OHCA survival. This included a volunteer first-responder system introduced in 2015, whose contribution to the reported outcomes is unclear.<sup>18</sup>

Additionally, a 2020 meta-analysis<sup>19</sup> pooled data from the RCT<sup>15</sup> and two of these observational studies<sup>17,18</sup> to report an OR for survival of 1.51 (95% CI: 1.24–1.84) when a volunteer first-responder was activated via mobile phone (compared with a standard response group).

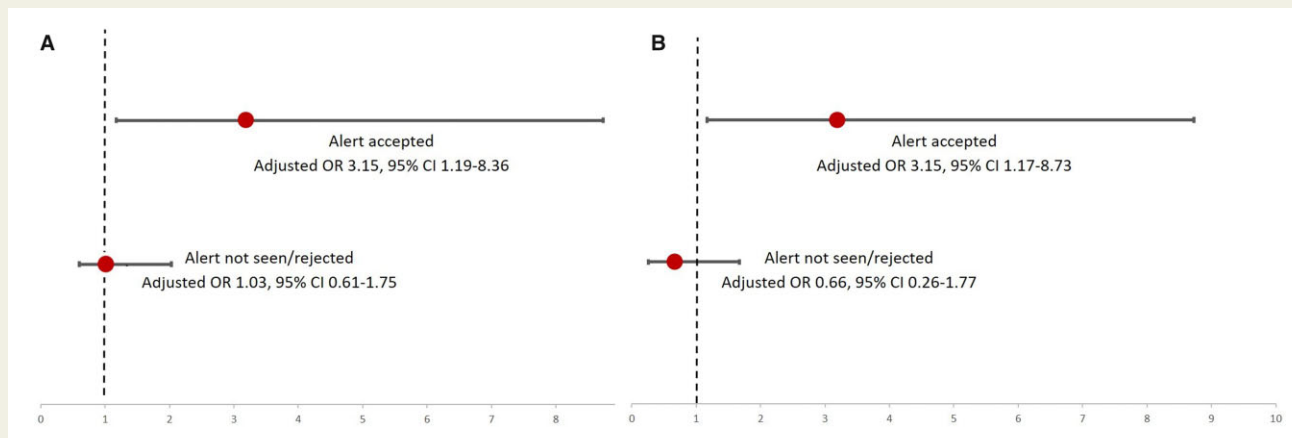
In a study published since these reviews, in Denmark (2017–18) volunteer first-responders arriving before EMS was associated with increased bystander CPR (OR: 1.8; 95% CI: 1.1–2.9) and bystander defibrillation rates (OR: 3.7; 95% CI: 2.0–6.8). However, there was no improvement in survival.<sup>20</sup>

There are many mobile-phone apps worldwide to alert members of the public to nearby OHCA. A recent review reported how such systems differ markedly in their alerting radii (from 200 m up to 10 km) and the number of volunteers alerted (up to 30).<sup>7</sup> Other systems have reported higher alert acceptance rates than in our study in

**Table 4** Logistic regression model—impact on survival to hospital discharge (London)

	Unadjusted OR (95% CI)	AOR (95% CI)
GoodSAM group		
Accepted	2.06 (0.99–4.27); $P = 0.052$	<b>3.15 (1.19–8.36); <math>P = 0.021</math></b>
Not seen/rejected	1.11 (0.71–1.73); $P = 0.66$	1.03 (0.61–1.75); $P = 0.908$
No alert	Reference	Reference
EMS response time	1.00 (0.99–1.99); $P = 0.011$	<b>0.99 (0.99–1.00); <math>P = 0.005</math></b>
Age in years	0.99 (0.98–0.99); $P < 0.001$	<b>0.98 (0.97–0.98); <math>P &lt; 0.001</math></b>
Gender		
Male	1.59 (1.26–2.00); $P < 0.001$	0.97 (0.73–1.30); $P = 0.844$
Female	Reference	Reference
OHCA witnessed status		
EMS	9.21 (6.41–13.2); $P < 0.001$	<b>7.70 (4.76–12.5); <math>P &lt; 0.001</math></b>
Bystander	4.12 (2.91–5.82); $P < 0.001$	<b>1.84 (1.25–2.71); <math>P = 0.002</math></b>
Unwitnessed	Reference	Reference
CPR performed by		
EMS	5.37 (3.90–7.41); $P < 0.001$	Not calculated <sup>a</sup>
Bystander	1.93 (1.42–2.62); $P < 0.001$	1.09 (0.77–1.56); $P = 0.621$
Not performed	Reference	Reference
Bystander AED		
Yes	2.11 (1.41–3.16); $P < 0.001$	1.38 (0.82–2.33); $P = 0.227$
No	Reference	Reference
Initial rhythm		
VF/VT	33.6 (22.8–49.4); $P < 0.001$	<b>27.9 (18.4–42.3); <math>P &lt; 0.001</math></b>
PEA	3.96 (2.55–6.14); $P < 0.001$	<b>2.42 (1.51–3.90); <math>P &lt; 0.001</math></b>
Asystole	Reference	Reference
<b>Location type</b>		
Non-residential	2.88 (2.28–3.63); $P < 0.001$	<b>1.66 (1.23–2.25); <math>P = 0.001</math></b>
Residential	Reference	Reference
Distance from nearest AED	1.00 (0.99–1.00); $P = 0.13$	1.00 (1.00–1.00); $P = 0.35$

<sup>a</sup>EMS performed CPR for all of the cases that were EMS-witnessed, therefore not calculated by SPSS (redundancy). Bold values are statistically significant ( $P < 0.05$ ).



**Figure 3** Adjusted odds ratios (with 95% confidence intervals) for 'Alert accepted' and 'alert not seen/rejected' groups, with 'No GoodSAM alert' (dotted line) as reference in (A) London and (B) East Midlands.



**Table 5** Logistic regression model—impact on survival to hospital discharge (East Midlands)

	Unadjusted OR (95% CI)	AOR (95% CI)
GoodSAM group		
Accepted	2.34 (1.00–5.46); <i>P</i> = 0.05	<b>3.19 (1.17–8.73); <i>P</i> = 0.024</b>
Not seen/rejected	0.73 (0.35–1.50); <i>P</i> = 0.39	0.66 (0.26–1.77); <i>P</i> = 0.378
No alert	Reference	Reference
EMS response time	1.00 (1.00–1.00); <i>P</i> = 0.97	1.00 (1.00–1.00); <i>P</i> = 0.818
Age in years	0.96 (0.95–0.97); <i>P</i> < 0.001	<b>0.96 (0.94–0.97); <i>P</i> &lt; 0.001</b>
Gender		
Male	1.76 (1.02–3.02); <i>P</i> = 0.041	1.29 (0.65–2.52); <i>P</i> = 0.467
Female	Reference	Reference
OHCA witnessed status		
EMS	1.06 (0.14–8.28); <i>P</i> = 0.96	1.37 (0.15–12.3); <i>P</i> = 0.778
Bystander	2.06 (1.22–3.48); <i>P</i> = 0.007	<b>2.13 (1.09–4.15); <i>P</i> = 0.028</b>
Unwitnessed	Reference	Reference
CPR performed by		
EMS	0.61 (0.08–4.71); <i>P</i> = 0.63	Not calculated <sup>a</sup>
Bystander	0.84 (0.52–1.38); <i>P</i> = 0.84	0.73 (0.39–1.41); <i>P</i> = 0.350
Not performed	Reference	Reference
Initial rhythm		
VF/VT	12.1 (6.32–23.1); <i>P</i> < 0.001	<b>10.7 (5.09–22.3); <i>P</i> &lt; 0.001</b>
PEA	2.85 (1.32–6.18); <i>P</i> = 0.008	<b>3.94 (1.66–9.37); <i>P</i> = 0.002</b>
Asystole	Reference	Reference
Location type		
Non-residential	3.16 (1.84–5.42); <i>P</i> < 0.001	1.73 (0.87–3.44); <i>P</i> = 0.121
Residential	Reference	Reference

<sup>a</sup>EMS performed CPR for all of the cases that were EMS-witnessed, therefore not calculated by SPSS (redundancy). Bold values are statistically significant (*P* < 0.05).

the Netherlands (27%),<sup>21</sup> USA (23%),<sup>22</sup> Denmark (51%),<sup>20</sup> and Sweden (65%).<sup>15</sup>

Other systems also report many more responders available per incident<sup>20,23</sup> than in our study, and so the chance that any given alert will have at least one person accept is higher. GoodSAM should attempt to increase its responder numbers but, until this happens, overcoming behavioural barriers to an individual accepting an alert is important to efforts to optimize the GoodSAM system.

In this study, we did not have precise information about the number of responders and AEDs registered on the GoodSAM app in either region, and so cannot reliably comment on the effect of either responder- or AED-density on outcomes. A study from the Netherlands suggests that at least 10 volunteer first-responders and two public-access AEDs are needed in every km<sup>2</sup> for an optimum response.<sup>24</sup>

## Clinical implications

The imprecision, indirectness, and risk of bias mean that this study likely represents a very low certainty of evidence according to the Grading of Recommendations, Assessment, Development and Evaluations framework<sup>25</sup>: i.e. the true effect might be different to the effect estimated in this study. The improvement in survival to hospital discharge associated with a GoodSAM response may be due to increased and earlier provision of CPR and/or AED use, but it is

unclear whether this approach is superior to other strategies to strengthen the community response to OHCA.

A number of alerts were 'not seen' by the first-responder. Since this project GoodSAM have updated their system so that the audible alert siren can sound even when the mobile phone is in silent mode—a feature not available at the time of the study, and one possible explanation for this.

Almost all GoodSAM responders reported confidence in their ability to provide CPR and use an AED if asked to respond, and they rarely reported anxiety about responding.<sup>26</sup> In a similar volunteer first-responder system in the Netherlands, 13% of 189 first-responders questioned (in 2013–14) reported a 'severe' short-term impact on their psychological health, but by 4–6 weeks after the event, all first-responders reported either 'no' (81%) or 'mild' (19%) stress on the validated Impact of Event Scale.<sup>27</sup> In Denmark, perceived stress was low in 102 people (surveyed in 2018) 3 weeks after taking part in a resuscitation effort, and very few reported symptoms indicating post-traumatic stress disorder.<sup>28</sup>

The 'true positive' rate for OHCA following activation was 35% in London and 12% in East Midlands. There is marked difference in these figures, which might be partly explained by differences in the criteria used for 'potential OHCA' (see Table 1). Furthermore, other studies have reported that 53% (Denmark)<sup>20</sup> and 33% (Sweden)<sup>23</sup> of alerts were for subsequently confirmed OHCA. Activation for a non-

OHCA may reduce future motivation to respond,<sup>26</sup> so there is a need to optimize activation criteria across different systems.

EMAS notified GoodSAM responders up to (a radius of) 800 m away, whilst LAS did so up to 300 m. The proportion of alerts for OHCA when a GoodSAM responder was in range was higher in East Midlands (22%) than in London (6.7%), but alert acceptance as a proportion of GoodSAM alerts sent for OHCA was similar in both ambulance services—16% in London; 15% in East Midlands. It is therefore unclear how far the response radius can be increased before it affects the likelihood of accepting an alert. There are marked differences in geography between local ambulance service areas, and responder density may vary as well, so this optimum radius is likely to vary across the UK.

Set-up and maintenance costs for using GoodSAM in the OHCA response are modest,<sup>8</sup> so pursuing strategies to improve both volunteer first-responder and other interventions to improve the community response to OHCA is entirely reasonable. This should include widespread CPR/AED training, particularly of school-aged children.<sup>29,30</sup>

There is also ongoing work in the UK to accurately locate and optimize the placement of public-access AEDs,<sup>31</sup> as has been done elsewhere.<sup>32–34</sup> There is now a national public-access database ('The Circuit') whose information is available to all UK local ambulance services.<sup>35</sup>

Efforts to maximize the number of responders using the app will increase the number of potential OHCA for which a responder is alerted and/or accepts the alert. We also need further data about the proportion of GoodSAM responders who arrive prior to EMS and both quantitative and qualitative evaluations of their actions. The decision to respond is complex, so we should focus on behavioural science methodologies to help design interventions to improve response rates.<sup>26</sup>

## Strengths and limitations

We have reported survival to hospital discharge as the main outcome measure, as this is important to clinicians, researchers, patients, and their families.<sup>36</sup> Data on favourable neurological outcome and functional performance post-OHCA are not currently available from the OHCAO registry. This limitation means that we cannot report longer-term and favourable neurological outcomes, nor about what investigations or procedures survivors underwent in-hospital (e.g. percutaneous coronary intervention (PCI)). There are factors that might affect survival—such as time from collapse to CPR interval, time from CPR to ROSC, which form part of the validated Cardiac Arrest Hospital Prognosis score<sup>37</sup>—that we were also not able to account for.

Ambulance services submit data to the OHCAO registry when they start or continue resuscitation efforts, and the reliability of our findings partly depends on how accurate their determination of OHCA was. Additionally, EMAS did not submit data on bystander AED use and neither ambulance service provided data on whether or not public-access AEDs were actually available at the time of the OHCA, which is not always the case.<sup>33,38,39</sup> We collected data from two different time periods (and durations) making direct comparisons between the two EMS services difficult.

Although there is evidence of a difference in the odds of surviving where an alert is accepted (compared with no alert sent or alert not seen/rejected), we made no formal power calculation to detect such a difference. We are alert to the chance that this is a spurious statistically significant finding. We separated out the 'not seen/rejected' and 'no GoodSAM alert' groups (even though the ultimate effect—a responder does not go to a patient—is the same) as we considered the possibility that factors not already included in our modelling resulting in volunteer first-responders being available within a certain radius might also impact upon clinical outcome.

There was no common case identifier for GoodSAM and OHCAO registry data, so we matched data manually using date/time and incident location. There is the potential for error, resulting in erroneously not reporting incidences when GoodSAM was activated for confirmed OHCA.

Recognizing and accounting for all factors potentially relevant to OHCA survival and choosing an appropriately non-biased comparison group is difficult. It is possible that patients who are more likely to survive, by nature of some factor that we have not been able to account for, are more likely to get a GoodSAM response in the first place. However, the survival effect that we have reported did appear independent of the factors leading to issuing an alert. There was no survival advantage in the 'not seen or rejected' group over the 'no alert' group, and the adjusted OR for survival after alert acceptance remained statistically significant when alerts 'not seen or rejected' were taken as the reference group.

An approach used elsewhere<sup>20</sup> would be to take the alert accepted group and compare outcomes when responders did or did not arrive before EMS. Unfortunately, we could not determine whether or not a GoodSAM responder reached the patient after accepting an alert, nor what interventions they performed. Indeed, a GoodSAM responder could attend an alert without indicating alert acceptance (via a button press) on the app, leading to misclassification of the GoodSAM response in that circumstance. Thus, we have not been able to compare such outcomes here.

There were little missing outcome data. However, where data were missing, this was predominantly in the 'No GoodSAM alert' group [77/85 (91%) cases in London where survival to hospital discharge data was missing, and 29/40 (72.5%) cases in East Midlands]. This study suggests an independent association between a GoodSAM responder accepting an alert and improved survival to hospital discharge. The magnitude of the effect was similar in two different datasets from two different ambulance services, but the wide confidence intervals suggest imprecise results. Only 19–40% of the variability in the outcome measure was explained by the logistic regression model in London, and 11–29% in East Midlands. Additionally, many non-significant results in univariate analyses became significant in multivariate analysis. Multicollinearity tests suggest no association between covariates, but there are a few variables with small numbers. Our results may be spurious due to either chance or other confounding factors that we have not been able to account for fully in our modelling.

Our models may also be limited because survival to discharge has small samples within each of the GoodSAM response categories (e.g. London,  $n = 7$ , and East Midlands,  $n = 9$ , in the 'accepted' groups). Ideally, we would have used exact logistic models for the analyses,

but such analysis was not possible with the software (SPSS) used to perform our statistical analyses.

## Conclusion

We have reported a statistically significant improved survival to hospital discharge in the GoodSAM volunteer first-responder system, in two separate ambulance services, in analyses adjusted for factors that can influence cardiac arrest outcome. There is uncertainty in this finding. Alert acceptance rates were low, but there are substantial opportunities to increase the number of GoodSAM responders who accept an alert, and to optimize the interventions they provide thereafter.

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## Data availability statement

The data underlying this article were provided by the Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) registry at the University of Warwick, GoodSAM, London Ambulance Service and East Midlands Ambulance Service by permission. Data will be shared on reasonable request to the corresponding author with permission of the relevant party.

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